

A user friendly multi-catchments tool for the SWAT model

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ABSTRACT

A software system to manage SWAT results (*bsb.dbf* and *rch.dbf*) has been developed on a multi catchment scale. Regions such as Sardinia, Sicily, Portugal etc are, in fact, characterized by a large variety of ecosystems within complex catchments. The AVS2000 interface deals with one watershed at a time, but the aggregation of SWAT results about adjacent basins may be necessary for an integrated water resources management. To achieve this goal, an ArcView extension, called *multi-catch.avx*, has been developed.

The extension allows the user to select the subbasins within the basins under investigation and obtain statistical reports of the model output, from the *rch* and *bsb* tables, in the form of charts, statistics and maps. The tool helps water managers in the demanding problem of water management by automating the post processing operation when dealing with many catchments within a region. *Multi-catch.avx* uses the *bsb* and *rch* files of all the projects and dynamically permits making time and spatial analysis at the widest scale and creating maps in the ArcView environment. A project view is created where all the watersheds under study are displayed along with their subbasins. The user can dynamically visualize and analyse the spatial distribution of a chosen model output for all the active subbasins within the given basin, at a monthly or yearly time resolution. Moreover the *bsb* file of each project is aggregated to represent the whole basin under study and statistical indicators such as mean, standard deviation etc. are calculated. The newly developed ArcView extension has been utilized to map, and analyze 15 Swat projects within the Sardinian Region.

INTRODUCTION

Water resources management is a complex task in regions where no natural hydraulic connection between streams exists. Each watershed in such a region must be analyzed separately. Still, water resources management must deal with the hydrological systems as a whole. SWAT has demonstrated its potential in analyzing the water cycle and the related hydrologic fluxes at the catchment scale, but only one watershed at a time can be simulated. The result of each simulation is printed in a general (at a daily, monthly, yearly time resolution) form, letting the user decide how to treat the results, which statistics to make, etc. To get a global view of the entire system and the results obtained for the single catchments, it is required for the user to post process the results available from the single SWAT projects. We therefore developed a new ArcView extension called *multi-catch.avx* to enable SWAT users to make concurrent analysis of different hydrological fluxes of the water budget of many SWAT projects. This will be very important when, within a region, a large number of watersheds are modeled and all watersheds must be analyzed together in order to find, or to locate in time and space, critical situations within the whole system.

ARCVIEW EXTENSION DESCRIPTION

In the development of the *multi-catch.avx* extension two questions were addressed: 1) how to deal with situations when many catchments are present and need to be analyzed, and 2) how to organize the SWAT results to be optimally used by water managers.

The *multi-catch.avx* (vers. 1) has been developed in the Avenue programming language, and incorporates an external program, called *Extract_results.pl*, written in Perl (www.perl.org). The Perl script, dedicated to the treatment of the *bsb* SWAT output, uses the following algorithms:

$$X_{basin} = \sum_{s=1}^N \left(\frac{X_s \cdot A_s}{A_{tot}} \right)$$

where X_{basin} is the value of the specific parameter (precipitation, evapotranspiration, etc.) aggregated at the basin scale, X_s is the value of the corresponding parameter for the active subbasin s , A_s is the area of the subbasin, A_{tot} is the total area of investigation, and N is the total number of active subbasins.

Extract_results.pl enables the user to merge the monthly results on a yearly basis. The program needs the Perl environment to be installed (ActivePerl, with XBase and DBD-XBase modules).

The ArcView extension can be loaded directly in ArcView 3.1 or later versions. After the file *multi-catch.avx* is copied in the ARCVIEW EXT32 directory, it can be loaded in an ArcView project from the File drop down menu, selecting Extensions and Multi-catchments Swat Extension. The tool is visible within the Project, View, and Table sessions and its name is Multi-catchment tool. The *multi-catch.avx* works with the bsb files contained in the directory `\scenarios\default\tablesout` and the shape files contained in `\watershed\shapes` of each SWAT project. To make the extension work, it is necessary for the user to set an environment variable having the value of the directory where all the SWAT projects are located. The results created by the *multi-catch.avx* extension is automatically placed in the same directory.

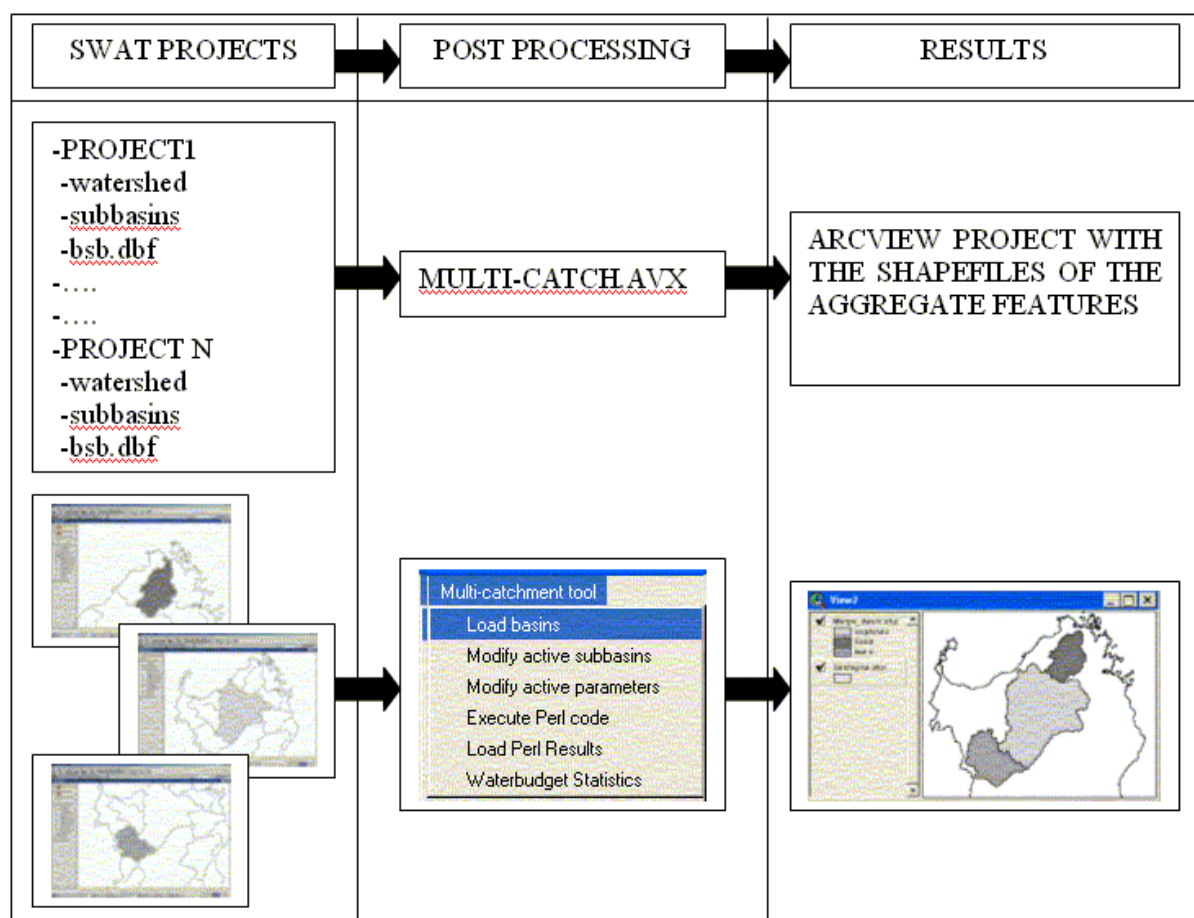


Figure 1. The ArcView *multi-catch.avx* uses the geographical information (watershed and subbasin) and the bsb tables to calculate statistics and create maps.

The tool works in 4 phases:

- 1) The user is required to chose the SWAT projects to be analyzed via the command `Load basin`. Once the projects are chosen, the Waters and Watersub shape files are loaded from the projects directory (`\watershed\shapes`) in a View, along with the relative bsb and rch tables.
- 2) The user can choose which subbasins of each basin should be considered active, so that all the statistics will refer only to these subbasins. This is achieved creating two tables (`define_bsb.dbf` and `bsb.refer.dbf`) that the user can modify in order to:

- a) Select which subbasins must be considered active in terms of contribution to the water balance, by clicking the extension command `Modify active subbasins`. If the user skip this command, all the subbasins are considered active.
 - b) Choose or later modify which parameters are significant for the statistics, by clicking the extension command `Modify active parameters`. By default, the active parameters are PreCiPitation, Snowmelt, Potential EvapoTranpiration, EvapoTranspiration, Water YieLD, Sediment YieLD, ORGanic Nitrogen, ORGanic Phosphorous, NO3 in SURface runoff .
- 3) The user can now run the Perl program and load the results into the project. In this phase the following operations are performed:
 - a) For each project two files are created (*Project_name_monthly*, *Project_name_yearly*). They have the same format as the bsb table;
 - b) The monthly table is then reorganized and saved in a new table, to have the years in the rows and the monthly values in the columns. This is important to show the hydrological regime and to design water management plans. This phase is quite time consuming because the transposing of the tables is computationally expensive.
 - c) The active subbasins are merged and one polygon is created. A new shapefile is created where each feature (one polygon) is represented by a basin.
- 4) The user is asked to choose which statistics are to be calculated. The results are displayed in the active View as a new theme, and a graduated legend is created.

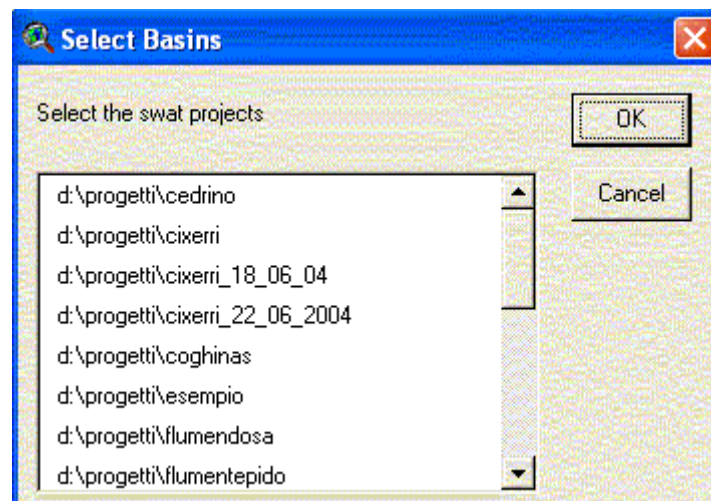


Figure 2. Through simple interfaces the user can choose the basins and the subbasins to be analyzed.

The user can select the time period for statistical evaluation and the required statistical measures such as mean, standard deviation, 25th percentile, or 75th percentile (Figure 3).

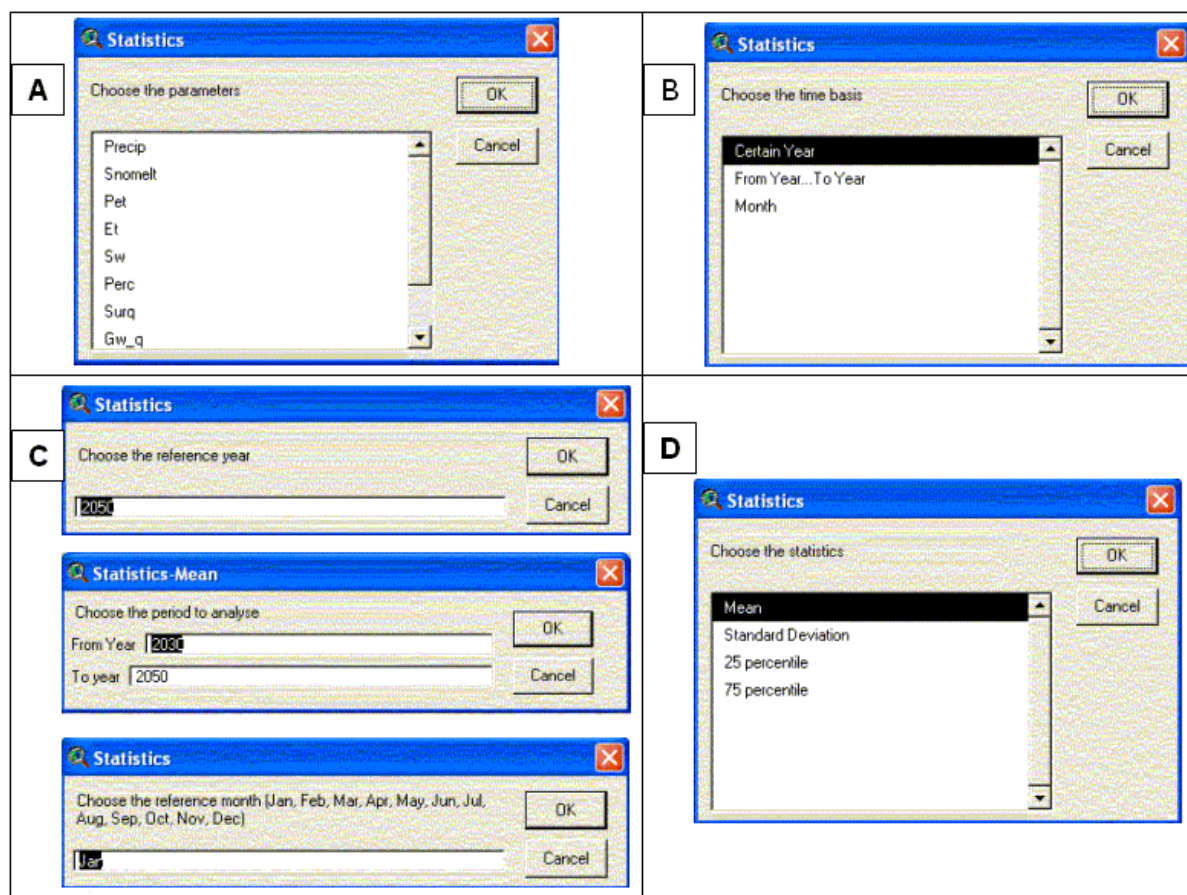


Figure 3. The user can choose the parameters (A) and the time period to be analyzed (B). For the yearly time resolution the user is allowed to choose between one year (e.g. 2050) or a time period (e.g. from 2030 to 2050); for the monthly time resolution the user is allowed to choose which months are to be analyzed (C).

APPLICATION OF THE EXTENSION

In 2002, a consortium made up of CRS4, TEI, PROGEMISA and NAUTILUS was created for the three years project “Piano di Tutela delle Acque” (PTA). One of the main topics of the project is the development of a multisectorial, integrated and operational Decision Support System (DSS) for the sustainable use of water resources at the catchment scale. A more detailed description of the PTA can be found in the article “A Decision Support System based on the SWAT model for the Sardinian Water Authorities” (P. Cau, E. Lorrai). The *multi-catch.avx* program has been used in the PTA to analyse and map the SWAT results. The main catchments of the island (15 basins) have been analyzed to gain an overview of the spatial distribution of the water cycle components of the whole system. In the following example all the subbasins were considered active. The parameters under investigation are precipitation, potential evapotranspiration, and water yield.

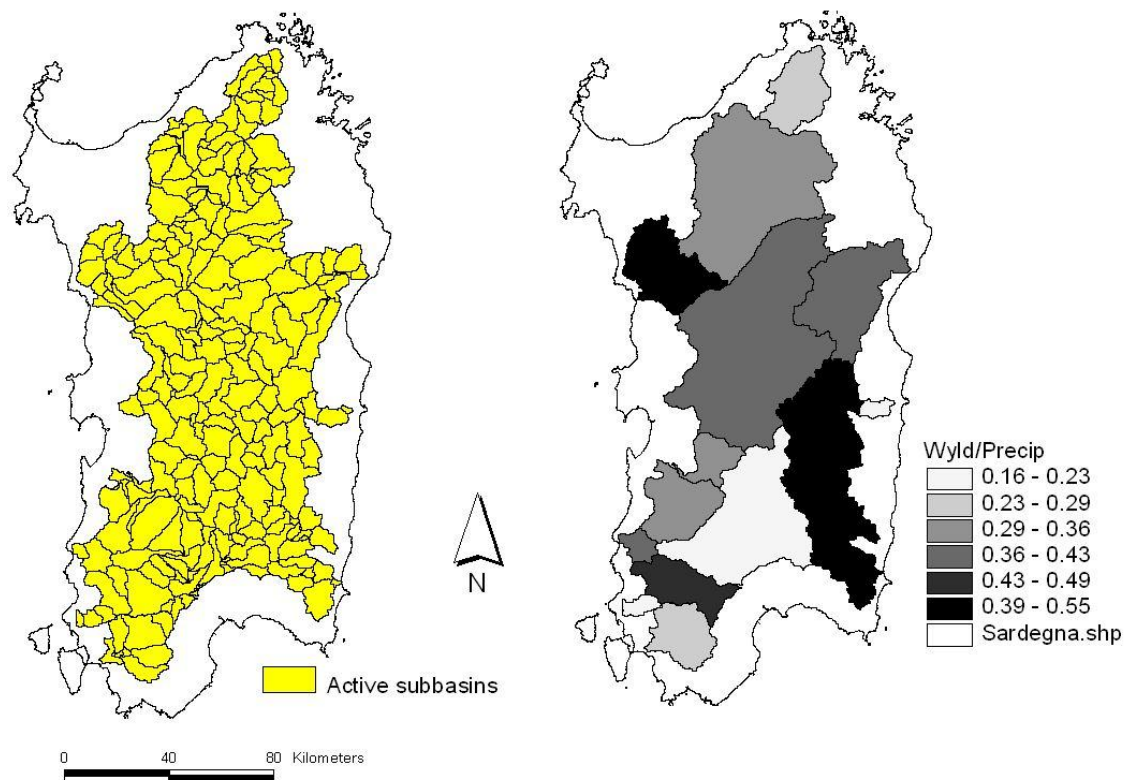


Figure 4. Application of the *multi-catch.avx* to a real case. The active subbasins (left) and the spatial distribution of the average water yield normalized by rainfall (right) for the time period 1922-1992 are shown.

CONCLUSION

The ArcView extension *multi-catch.avx* has been developed to facilitate water resources management in complex regions where a large variety of watersheds is investigated. So far, SWAT allows each watershed to be analyzed separately. Still, water resources management should treat the hydrological systems as a whole. The procedures implemented in *multi-catch.avx* make use of the bsb, rch tables and shape files (subbasin.shp and watershed.shp) and dynamically permit making time and spatial analysis at the regional scale and visualizing maps in the ArcView environment. Future versions will enforce the spatial analysis at the subbasin scale.

Acknowledgments

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References

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